Planning Level Cost-Benefit Analysis for Physical Separation at Confined Disposal Facilities

PURPOSE: This technical note is the fourth in a series providing guidance on evaluating the potential for recovery of dredged material from confined disposal facilities (CDFs) for beneficial use (BU). Olin-Estes and Palermo (2000a, 2000b) and Olin-Estes (2000) discuss physical separation concepts as they apply to dredged material recovery, mathematical relationships for estimating recoverable material, and methods for developing sampling plans for CDFs to support these evaluations. This technical note describes a conceptual approach to estimating the comparative cost benefit for separation as a volume reduction method, based on recoverable volume, processing cost, and disposal facility life and replacement cost.

BACKGROUND: The technical feasibility of separation as a management approach is dependent upon several factors, including the ability to identify and separate distinct fractions within the material that meet BU criteria. The economic feasibility of separation is dependent on the complexity of the separation treatment train, disposal and BU alternatives and costs, site-specific logistical considerations, and project scale.

The principal motivation for BU recovery of dredged material is the growing shortage of storage capacity in CDFs, coupled with the high cost to replace this capacity. The fundamental purpose of these technical notes is to assist in determining when material recovery is technically and economically feasible. Olin-Estes and Palermo (2000a, 2000b) and Olin-Estes (2000) provide strategies for obtaining and interpreting physical and chemical information necessary for this evaluation at the least possible cost. This technical note develops an approach for screening-level economic analysis of separation alternatives, together with methods for quantifying potential volume reduction for different processes, which can be used in planning-level decision making and in support of a detailed cost-benefit analysis. It presents the basic economic principles and approach utilized, followed by simple separation concepts and volume reduction calculations. Examples are developed for one-time and long-term dredging projects to illustrate the relative importance of the different variables involved.

INTRODUCTION: Although physical separation has been successfully demonstrated technically, the economic viability of full-scale implementation is difficult to determine based on overall project volumes and unit costs reported in the literature. Part of the difficulty can be attributed to the fact that costs associated with small volume demonstrations are typically high on a per-unit basis. In part, this is because mobilization and demobilization costs are relatively insensitive to the volume being processed: a larger project will distribute these costs over a larger volume, resulting in lower unit costs. For the most part, representative full-scale costs are difficult to extract from the literature or from other projects because they are heavily influenced by site-specific factors such as local labor cost, equipment availability, site accessibility, distance to water, terrain, weather and climate, material characteristics, disposal requirements and costs, and differences in what is included in reported costs. Some examples of total project costs and cost estimating sheets for soil remediation projects, however, can be found in U.S. Environmental Protection Agency (USEPA) (1999).

This technical note introduces a planning level approach to making cost comparisons between disposal and process alternatives and quantifying volume reduction, or volume recovery, potential. Site-specific cost information should be used when possible; cost ranges reported herein should be used primarily as a "reality check." Cost estimates falling significantly outside the cost ranges reported for similar projects should be closely scrutinized to determine the basis for the difference. Detailed costs should be developed for potentially viable alternatives based on the planning level cost-benefit analysis. These costs should be used in conducting a detailed economic analysis for the project.

ECONOMIC ANALYSIS: The benefits of physical separation and mechanical dewatering of dredged material are based on the next least cost dredged material disposal alternative. In the absence of separation and dewatering processing, the analyst must identify the most likely future dredged material disposal alternative (the base condition). Potential quantitative benefits of physical separation are reductions in cost and increases in revenue from the base condition to the physical separation alternative. The analysis assumes the in situ volume of sediment to be dredged will be the same for all alternatives.

Identifying the Base Condition

Step 1: Determine the period of analysis. Corps planning studies typically use either a 50- or 100-year planning horizon; however, a shorter period may be appropriate for the analysis of physical separation projects. The period of analysis should be of sufficient length to allow a life-cycle analysis of the benefits and cost of all alternatives.

Step 2: Define the project scope. Estimate the quantity and timing of dredged material to be disposed over the life cycle of the project planning horizon.

Step 3: Define the dredging and disposal alternatives. Disposal alternatives may include CDF disposal, a combination of CDF disposal and offsite disposal, or offsite disposal.

Step 4: Determine the base condition. From the available alternatives, determine the least-cost method of dredging and disposal without physical separation. This will establish the Base Condition from which to measure benefits of physical separation.

1. This analysis compares the cost of alternative dredging and disposal scenarios. The scenarios may assume different dredging technologies, different transportation methods and offloading costs at an offsite disposal area or CDF, and/or the cost of developing a disposal site. For example, when available CDF capacity is limited, material may be disposed offsite, dredging may be done with a smaller dredge (requiring less settling freeboard), or CDF capacity may be increased. The combinations of offsite disposal and CDF facilities (existing and developed) must be of sufficient size to receive the quantity estimated in Step 2. New CDF sites will incur site acquisition, permitting, and design cost and may require additional transportation cost. The

analysis should assume that the costs incurred for the new facilities are expended such that the new facility becomes available just as the existing facilities reach their capacity.

2. Calculate the average annual cost of dredging and disposal for each scenario. Correlate the cost of each action required (dredging, transportation, CDF construction, offsite disposal, etc.) with the timing of the action. This is illustrated in Figure 1. Discount the cost from the time incurred to its present value using the Federal discount rate[1]. Sum all the present values and amortize over the period of analysis. The least-cost method will have the lowest present value and lowest average annual cost. This method is the base condition and will be used to measure the cost and benefits of physical separation. A conceptual example of the base condition is depicted in Figure 1. It shows the existing CDF being expanded by raising the berms and then later being replaced by construction of a new CDF of sufficient capacity to last the remainder of the period of analysis.

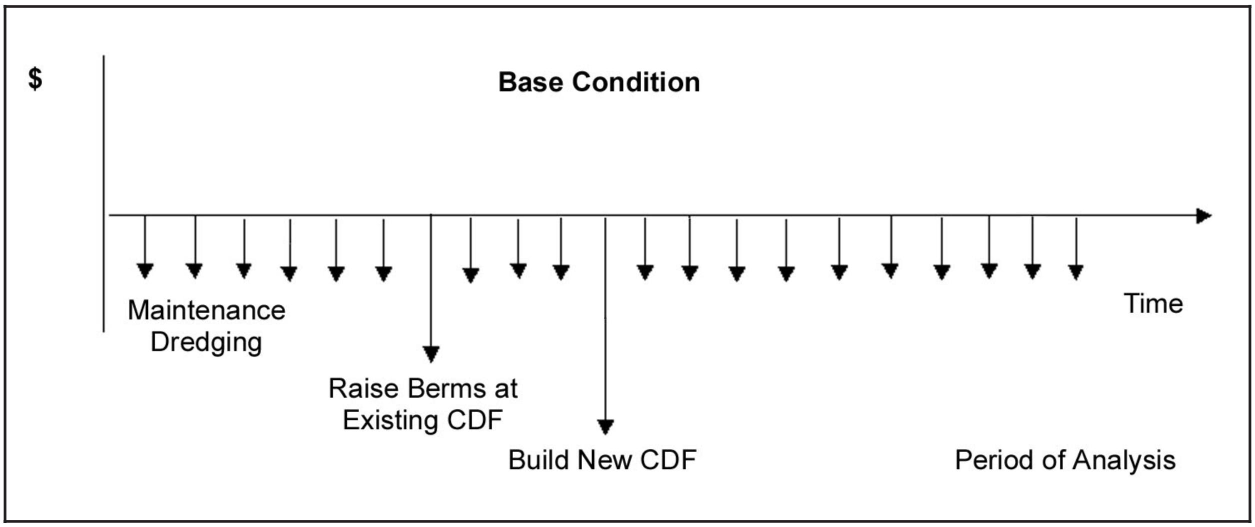

Figure 1. Base condition

Formulating Physical Separation Alternatives

There are three general separation scenarios that could be formulated to extend the life of an existing CDF:

1) Volume reduction of incoming material.

2) Capacity recovery, i.e., removal of materials previously placed.

3) Capacity recovery and volume reduction of incoming material.

1 Section 1.4.11 of the Economic and Environmental Principles and Guidelines for Water and Related Land Resources Implementation Studies requires discounting of future monetary values to present values. The discount rate is established each year and published in an Economics Guidance Memorandum by the Planning and Policy Division of the Directorate of Civil Works.

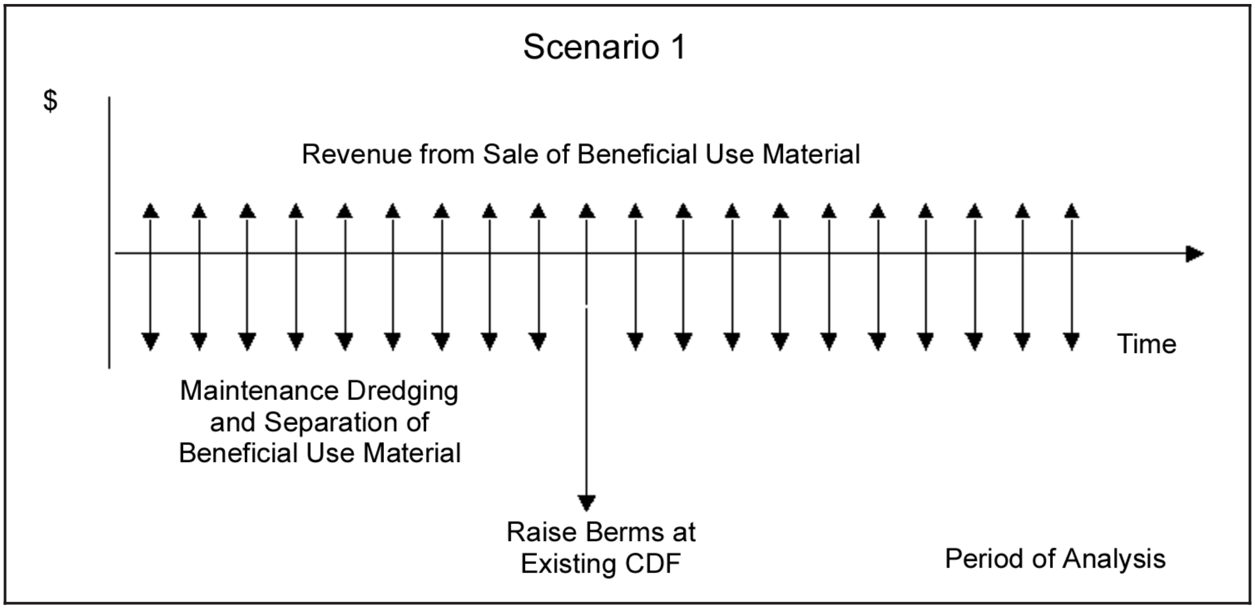

Figure 2. Scenario 1, separation of incoming material

Where CDF capacity is diminishing, volume reduction of incoming material might seem to be indicated in all cases (Figure 2). However, the benefit will be dependent upon the nature of the incoming material and the amount of volume reduction to be derived compared to the processing cost incurred. In cases where the incoming material is not suited to volume reduction, then removal of previously placed materials to recover in-CDF capacity might be another option, depending upon the nature of the materials previously placed (Figure 3). Where both incoming and previously placed materials lend themselves to volume reduction, the third alternative could be implemented (Figure 4).

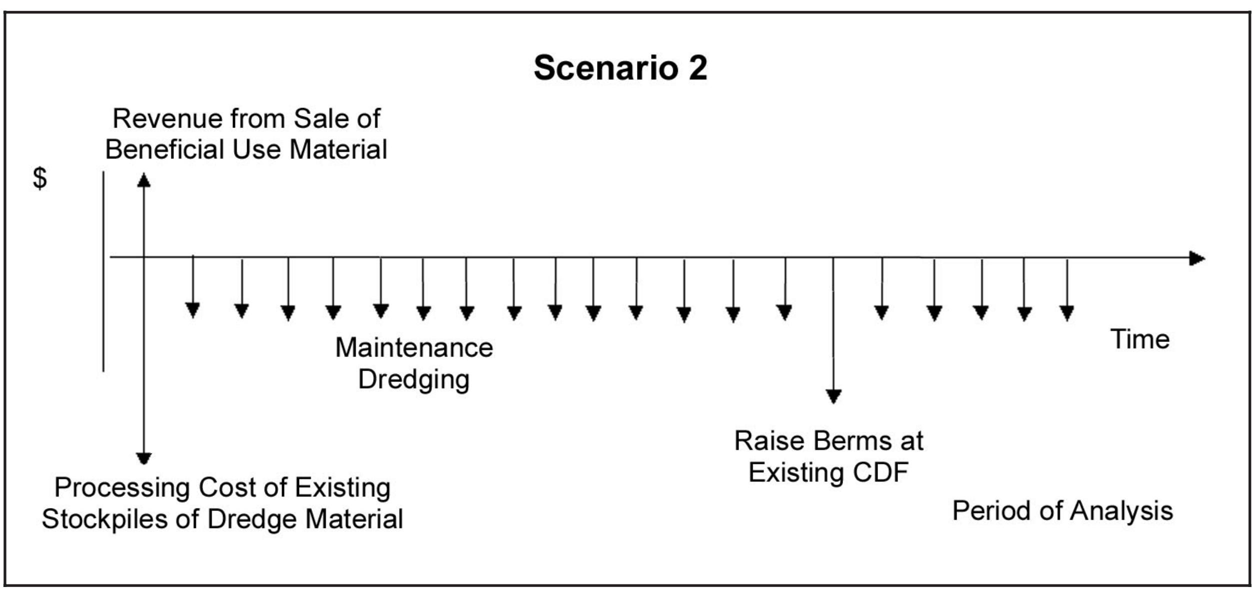

Figure 3. Scenario 2, processing material removed from CDF

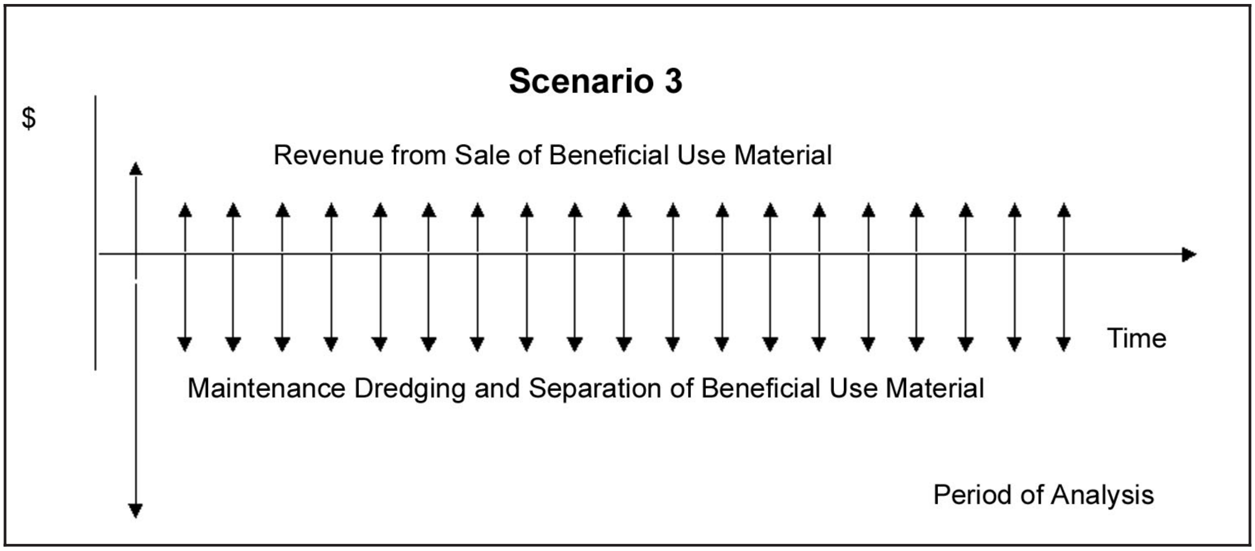

Figure 4. Scenario 3, processing incoming material and material removed from CDF

In the first scenario, volume reduction of incoming material (Figure 2), expansion of the CDF is deferred relative to the baseline condition depicted in Figure 1. This is indicated here by a downward arrow for raising the berms of the existing CDF. Revenues from the sale of BU material produced by processing incoming materials are represented by the upward arrow at the time of dredging and processing. This revenue is assumed to be realized with every dredging and processing event for purposes of illustration, but is not guaranteed. Regulatory restrictions on use of the material, public acceptance, and market demand will determine whether the material will be revenue producing.

Comparing the base condition (Figure 1) to scenario 2 (Figure 3), the processing of material removed from the CDF also postpones the need to expand the capacity of the CDF. In this example, the need for a new facility is completely eliminated during the period of analysis. Revenues from the sale of BU material produced by processing previously placed materials are represented in Figure 3 by the upward arrow at the time of the excavation and processing. The relative rates of material processing and maintenance dredging will determine how far into the future the need for additional capacity is postponed.

Figure 4 represents the third scenario, in which incoming material is separated and in-place material is processed to recover usable material. In this conceptual example, both the expansion of the existing CDF and the construction of a new CDF are eliminated for the period of analysis. The downward arrows are longer than in the base condition, reflecting the added cost of processing incoming material.

Evaluating and Comparing Alternatives

Step 1: Evaluate the alternatives. Calculate the average annual cost of each alternative and compare to the base condition. The net benefits of the alternative are equal to the average annual cost of the base condition less the average annual cost of the alternative. The benefit-to-cost ratio is equal to the average annual cost of the base condition divided by the average annual cost of the alternative. Alternatives with positive net benefits (a.k.a. BCR 1) are economically efficient alternatives. The alternative with the greatest net benefits maximizes benefits.

Step 2: Calculate average annual cost. Although specifics will vary between sites and the alternatives being evaluated, the economic analysis essentially follows the same series of steps. These are described in the following paragraphs. The analysis can be readily incorporated into a spreadsheet, facilitating comparison of several alternatives. This has been done for two examples, which are included as Appendix C.

I. Project Assumptions. This might include type of work, available disposal capacity, and base condition, for example:

a. Type of dredging: new channel construction followed by maintenance dredging over the period of analysis.

b. Disposal alternatives: no existing CDF.

c. Base condition: CDF disposal, without separation or mechanical dewatering (no material will go offsite).

II. Calculate Base Condition

a. Develop initial construction/dredging costs. These will be engineering costs, including all items that will impact the total project costs. Such items include mobilization/ demobilization, dredging, dewatering, transportation, and placement. Any associated costs, such as CDF construction or expansion required to accommodate the initial (new-work construction) dredged material, must also be included in the construction costs. (Existing capacity is treated as a sunk cost, and is not factored into the evaluation.) Establish a construction period, annual quantity dredged, and total annual construction cost.

b. Calculate interest during construction (IDC). IDC is the value adjustment of pre-base year construction costs, and is an economic cost that will not actually be paid by any party involved with the project. (In economic analyses, the base year refers to the first full year the project is operational.) IDC should be applied to all construction costs, including all costs associated with channel dredging as well as any placement costs, such as CDF construction or expansion. (Sunk construction costs for an existing CDF are not considered pre-base construction costs. Costs for a CDF constructed specifically for the project defined for the period of analysis are considered pre-base construction costs.) The calculation is done to bring all construction costs to the base year and make them equivalent in their time value. IDC should be calculated using the formula:

$$IDC = P * (1 + i)^t - P \tag{1}$$

where

P = Annual construction amount
i = Federal discount rate
t = Time (years from construction year to base year)

c. Calculate initial investment. The initial construction cost will equal the sum of all construction costs and IDC for each construction year.

d. Develop maintenance dredging cycle and associated costs, including mobilization/demobilization, dredging, dewatering, transportation, and placement. Sufficient placement capacity must be available to accommodate all maintenance material for the entire period of analysis. All associated placement costs, such as CDF construction or expansion, as well as facility maintenance costs, must be developed and included. Timing for future costs must be established.

e. Calculate net present value (NPV). Determine NPV of all costs, including construction costs, IDC, and anticipated future expenditures. Summing the present value for each project year, beginning with the base year (project year 1) and continuing throughout the period of analysis, results in the present worth of all project costs. NPV is given by

$$NPV = \sum P \, [1/ (1+i)^t] \tag{2}$$

where

P = Annual cost
i = Federal discount rate
t = Time (project year)

f. Compute average annual equivalent values (AAEV). Through amortization the previously calculated present worth can be converted to an average annual equivalent. This calculation results in representation of the total project costs spread uniformly across the period of analysis. Average annual equivalent values have a common price level and base year, making it simple to calculate potential benefits. AAEV is given by

$$AAEV = (NPV)^* \, (i)^* \, [(1 + i)^n / (1 + i)^{n-1}] \tag{3}$$

where

NPV = Net present value (all costs)
i = Federal discount rate
n = Project life

g. Determine the base condition. If more than one alternative is being considered for the base condition, these steps must be completed for each alternative. The least costly alternative, including initial investment, IDC, and future maintenance costs, is the base condition. The selected alternative will have the lowest average annual equivalent value.

III. Calculate Separation Alternatives

a. Develop construction/dredging costs. These will be engineering costs, including all items that will impact the total project costs. Such items include, but are not limited to, mobilization/demobilization, dredging, dewatering, separation, transportation, and placement. Separation alternatives must also consider the value of the coarse material as a negative cost, or profit, from the process. Establish a construction period, annual quantity dredged (in situ basis), annual quantity residuals requiring placement or offsite disposal, and quantity suitable for beneficial use. Methods for estimating recoverable and residual volumes follow in the section titled "Volume Reduction Estimating."

b. Calculate interest during construction (IDC). IDC must be calculated for each construction (new work) year using Equation 1.

c. Calculate initial investment. The initial construction cost will equal the sum of all construction costs and IDC for each construction year.

d. Develop maintenance dredging cycle and associated costs, including mobilization/demobilization, dredging, dewatering, separation, transportation, and placement. Sufficient placement capacity (either CDF or offsite) must be available to accommodate all residual maintenance material for the entire period of analysis. All associated placement costs for the disposal alternative, such as CDF construction or expansion, facility maintenance costs, and transportation and unit disposal costs, must be developed and included. Timing for future costs must be established.

e. Calculate net present value (NPV). Determine NPV of all costs, including construction costs, IDC, and anticipated future expenditures. These calculations are completed using Equation 2.

f. Compute the AAEV for each alternative using Equation 3.

g. Select the separation alternative. If more than one separation alternative is being considered, these steps must be completed for each alternative. The least costly alternative that accommodates all future maintenance material, including initial investment, IDC, and future maintenance costs, is the selected separation option. The selected plan will have the lowest AAEV.

IV. Calculate Benefits from Separation. The benefit to separation is the savings between the annualized base condition costs and the annualized selected separation alternative costs. If separation is not more efficient than the base plan, the benefits from separation will be negative. Among separation alternatives with comparable benefits, intangible benefits, such as reduced contaminant emissions or habitat creation, may be factored into the final selection.

VOLUME REDUCTION ESTIMATING: Economic analysis requires estimation of in situ sediment volumes and relative volumes of recoverable materials and residuals requiring disposal. Procedures for estimating the percent material by mass meeting BU specifications (recoverable materials) were presented in Olin-Estes and Palermo (2000a). Mass and volume percentages are not equivalent, however, and this is central to the concept of volume reduction. The volume represented by a given mass percent of sand, for example, is a function of the specific gravity of the relative sediment fractions and the void ratio of the material. The relative proportions and specific gravity of the principal sediment fractions (sand, fines, organics) and in situ void ratio can be determined from bench-scale characterization of the material to be processed. Nomographs were developed for a hypothetical material to illustrate the variation in percent sand by volume versus percent sand by mass (Figure 5). Similar nomographs can be developed using site-specific information and the mathematical and geotechnical relationships describing the sediment fractions for a unit mass of sediment. By bounding the analysis within a range of values representative of

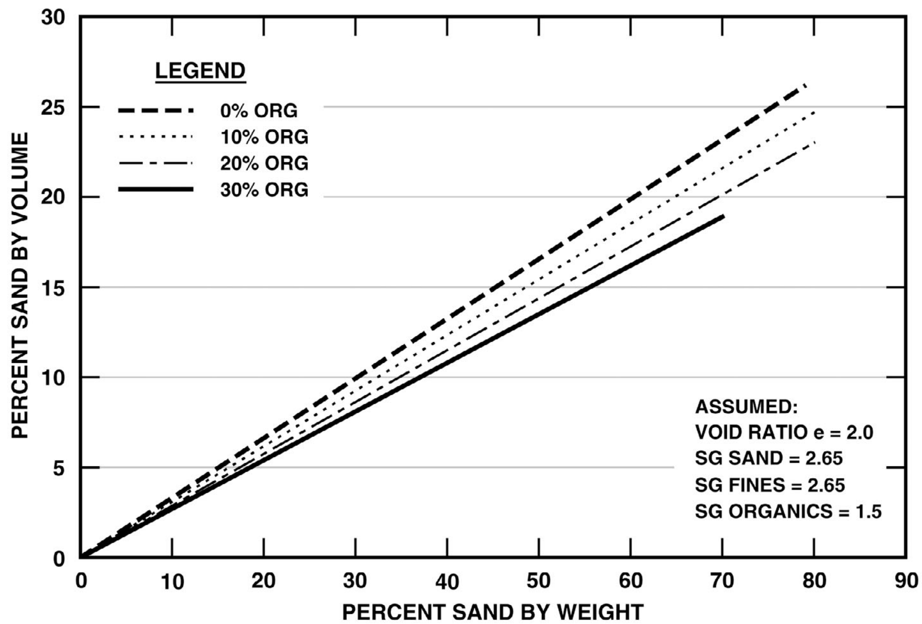

Figure 5. Percent sand by volume versus percent sand by weight, for void ratio 2.0 and organic specific gravity of 1.5

the entire deposit, coupled with proportional bulk sediment volumes, the best- and worst-case volume reduction potential for the total project volume can be roughly estimated.

In the recovery of a specified fraction from the bulk material, the material is slurried and separated around a "cut size" using equipment best suited to make the specified separation. Where a coarse/fine separation is desired, the cut is typically made at about 75 µm. The material does not separate sharply at this cut size, however. A percentage of the material below the cut size will report with the coarse material. Similarly, a percentage of the material above the cut size will report with the fines. These proportions will vary depending upon the type and efficiency of the selected process. The major products will typically include a coarse fraction, a fine fraction, and a wastewater stream. These concepts are illustrated in Figures 6 and 7.

Solids Mass Balance - Although the sediment or dredged material will be slurried with water in the course of dredging and processing, conceptually it is helpful to look at the solid and water balances separately. Figure 6 is a simplification of the actual distribution of solids.

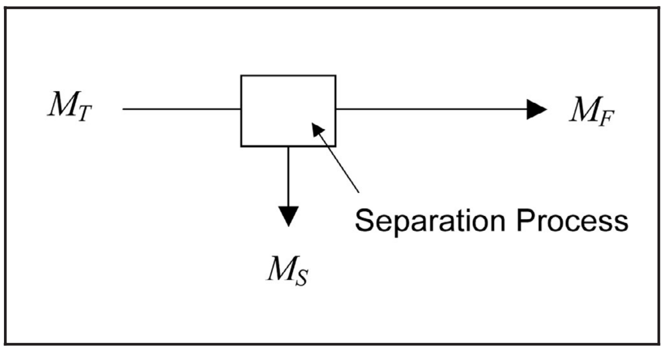

Figure 6. Solids mass balance diagram

M_T is the solids mass flow rate (M/T) from a dredge or CDF excavation process, and is represented by the following equation:

$$M_T = Qs\rho_s \tag{4}$$

where

Q = the volumetric flow rate to the separation process, V/T

s = percent solids by volume, as decimal, unitless

ρ_s = particle density, M/V

M_S is the solids mass flow rate of the coarse material from the separation process, and is given by

$$M_S = x_m M_T c \tag{5}$$

where

x_m = efficiency of coarse solids separation on a mass basis, unitless (decimal)

c = percent coarse (specified cut size) by mass in bulk material, unitless (decimal)

M_F is the solids mass flow rate of the fines from the separation process, and is given by the following, assuming 100 percent of the fines reports with the process overflow. The first term represents the coarse material that reports to the fine fraction as a result of process inefficiency:

$$M_F = M_T c\ (1 - x_m) + M_T\ (1 - c) \tag{6}$$

Volumetric Water Balance – Q_X is the volumetric flow rate of water to the separation process (Figure 7). Q_F is the flow rate reporting with the fines, typically the bulk of the processing water. Q_S is the flow rate reporting with the coarse fraction. Some of this water will be free draining (Q_{Free}), and will be captured and returned to the process or released as effluent. The residual pore water makes up the remainder (Q_{Pore}). Q_F and Q_{Free} represent volumetric flows that must be managed. Following a settling or dewatering process to remove solids, they may be recirculated through the process, or treated and released as effluent. Process slurries are typically fairly dilute, with 10 to 15 percent solids by volume being representative. Process water volumes are therefore relatively high. Volumes reported in the literature ranged from approximately 1,000 gallons to 1,700 gallons process water per cubic yard processed and dewatered sediment.

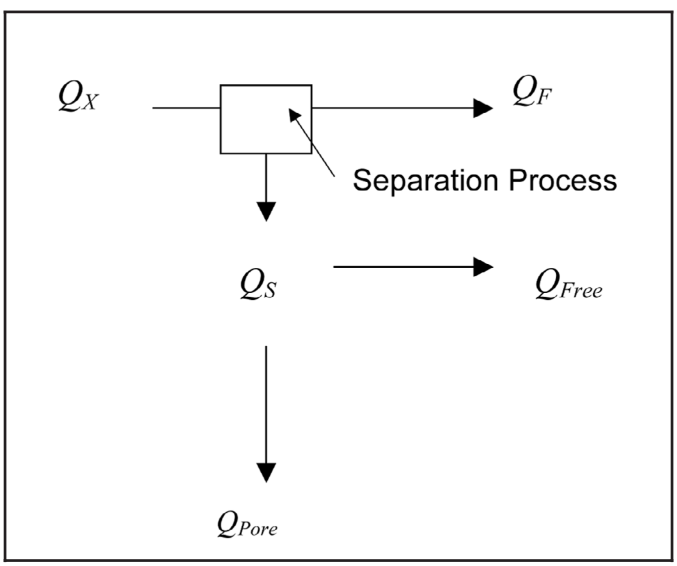

Figure 7. Water balance diagram

The coarse solids fraction is typically targeted for beneficial use and the fine fraction for onsite or offsite disposal. The disposal volume of the fine fraction relative to the disposal volume for the bulk material represents the volume savings to be realized. Where material is to be transported offsite, weight reduction may be the controlling parameter. Volume reduction estimates can be refined with bench- or pilot-scale process testing. A fractional bulking factor was developed to facilitate quantitative estimation of volume reduction potential based on initial and final material properties derived from such testing. This is potentially useful in comparative process evaluations, such as different dewatering techniques, and may form the basis for cost justification of one process over another.

Define in situ volume V_{T_i} as follows:

$$V_{T_i} = V_{s_i} + V_{F_i} + V_{V_i} \tag{7}$$

where

V_{T_i} = volume total, in situ or initial

V_{s_i} = volume sand, in situ or initial

V_{F_i} = volume fines, in situ or initial

V_{V_i} = volume voids, in situ or initial

Define dewatered sediment volume V_{T_f} (final total volume) as follows:

$$V_{T_f} = (1 - x_v) V_{s_i} + V_{F_i} + V_{V_f} \tag{8}$$

where

x_v = efficiency of sand removal, by volume

V_{V_f} = volume voids, final

Define the overall bulking factor as

$$b = \frac{V_{T_f}}{V_{T_i}} \tag{9}$$

Expressing material volumes in terms of mass and density, the bulking factor can be expressed in terms of initial and final material properties, which are readily measured before and after processing. The derivation of this factor is described in Appendix A, and yields the following expression:

$$b = \frac{\left(1+w_f\right)\left[\left(1-x_m\right)M_{S_i} + M_{F_i}\right]\rho_{t_i}}{\left(1+w_i\right)\left(M_{S_i} + M_{F_i}\right)\rho_{t_f}} \tag{10}$$

where

w_i and w_f = water content, as a decimal

M_{S_i} = mass sand, in situ or initial

M_{F_i} = mass fines, in situ or initial

ρ_{t_i} = total or wet density, in situ or initial

ρ_{t_f} = total or wet density, final

An estimate of the disposal volume following processing can therefore be obtained based on the hydrographic survey and projected dredging depths V_{T_i}, and the bulking factor derived by measuring the initial and final water content, sand and fine mass, and wet density of representative samples, thus:

$$V_{T_f} = b\,V_{T_i} \tag{11}$$

The net volume recovery is then

$$\Delta V = V_{T_i} - V_{T_f} \tag{12}$$

Conceptually, it is valuable to consider potential volume reduction in the context of the processes being utilized. Depending upon the process under consideration, this may be a time-dependent value. For example, hydraulically dredged and placed materials require additional disposal volume to provide adequate freeboard and settling depth for effective solids capture. The initial disposal capacity required for hydraulic placement will therefore be much larger than for mechanically dredged, or mechanically dewatered, materials. Figure 8 illustrates the time-dependent nature of volume recovery, which determines

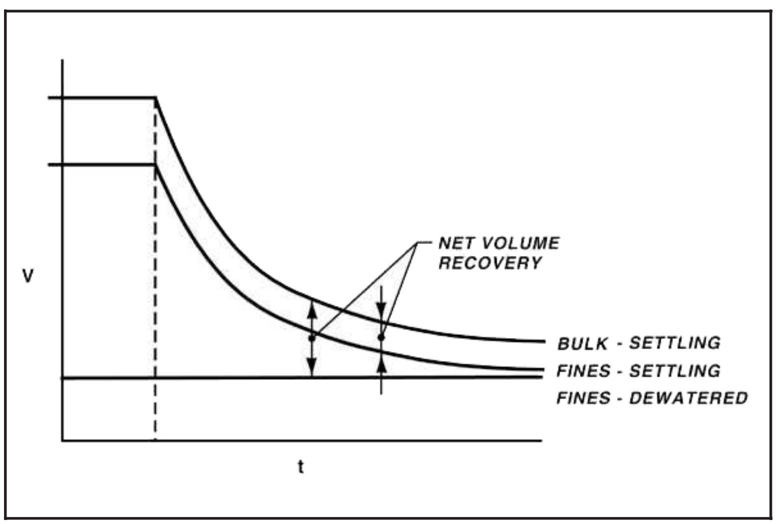

Figure 8. Relative disposal volumes as a function of time for bulk and separated, hydraulically placed material, and separated, mechanically dewatered material

the initial disposal volume for hydraulically placed sediments versus disposal volume requirements for mechanically dewatered sediments.

The necessary volume and cost comparisons will be site specific depending upon excavation method (mechanical or hydraulic), use of separation for BU material recovery, and dewatering method employed.

DESIGN VALUES: Some cost information is available for the following cost components. These would form the basis of a detailed economic analysis, applying the unit costs to the relative volume estimates as developed in the preceding section.

- CDF construction.
- Dredging.
- Excavation.
- Separation/dewatering.
- Offsite transportation and disposal.

The cost ranges reported in this document are intended to serve primarily to provide a frame of reference in the cost evaluation process. It is incumbent upon the planner to obtain site-specific cost information for detailed decision level planning and economic analysis.

CDF Construction. Reported CDF construction costs for the Great Lakes area were obtained and updated[1] (Table 1). The complete listing is included as Appendix B. The least costly alternative for expanding CDF capacity is typically to raise the dikes of an existing facility. Lateral expansion of an existing CDF is likely the next least cost alternative, provided space is available and public and environmental issues do not preclude construction. New CDF construction is expected to be the most expensive alternative. Note that the estimated \$20-\$50/cubic yard new construction cost may be comparable to that of transporting to and disposal at a commercial landfill, depending upon the nature of the material (whether covered by the Toxic Substances Control Act (TSCA) or not) and transportation costs. However, for a landfill to be a viable alternative to CDF disposal, the landfill must be suitably permitted to accept the material and have the necessary capacity.

Table 1
CDF Construction/Expansion Cost Estimates for Great Lakes Area

Alternative	Unit Cost
Raise dikes of existing facility	Typically<\$2/cubic yard capacity added
Lateral expansion of existing facility	\$5-\$10/cubic yard
New CDF/New site	Estimated at \$20-\$50/cubic yard*

* Costs as high as \$86-\$195/cubic yard were estimated for construction of a new shoreline CDF to receive sediments from a Superfund site in the northeast United States, where foundation materials would first have to be excavated and replaced with competent fill (Personal communication, Rose Schmidt, 10 Dec 2001).

1 Personal communication, Jan Miller, USACE, July 24, 2000.

Dredging. Dredging costs are included as part of the economic analysis. Where physical separation is employed, the type of dredge or processing rates may be determined by separation plant capacity and slurry feed requirements. Dredging costs may be impacted by this factor. These costs typically include a substantial mobilization/demobilization cost, and unit costs incremented based on the volume to be dredged. Costs may differ substantially between regions, and be strongly influenced by the distance the contractor has to travel to the site. The level of contamination of the sediment will typically influence unit costs as well.

Reported costs for mechanical dredging of clean sediment in the north-central region of the United States range from \$3.53 to \$10.46/m^3 (\$2.70/yd^3 to \$8/yd^3), with costs incremented downward above a specified volume threshold that varies from 11,475 to 114,750 m^3 (15,000 to 150,000 yd^3). Mobilization/demobilization and bond costs for this region ranged from 2 to 38 percent of the total contract cost. Mobilization/demobilization costs in excess of \$1 million are not uncommon. McCorquodale, Selvidge, and Bennett (2000) provide a useful summary comparison of cost and suitability of dredging equipment developed for the Great Lakes area. Based on that report, clamshell, conventional excavation, portable hydraulic, and plain suction dredges all fall within a low cost range. Cutterhead and airlift dredges are classified as moderate in cost, and cable-arm dredges as high cost. Cost ranges of approximately \$15-\$40/m^3 (\$12-\$31/yd^3) were cited, with lower unit costs associated with high-volume projects (over 50,000 m^3 (65,400 yd^3).

Excavation. Cost estimates for hydraulic excavation of existing dredged material stockpiles were obtained for a site in the north-central region (U.S. Fiscal Year (FY) 2000). Costs included redredging, transferring, and disposing of uncontaminated dredged material from two dredged material stockpile areas. Mobilization, demobilization, and bond costs were additional. Costs ranged from \$2.10 to \$8.00 per cubic yard for a 60,000-yd^3 (45,873-m^3) site and \$1.62 to \$11.00 for a 500,000-yd^3 (382,277-m^3) site. The effort was completed over a period of 2 years.

A small volume of dredged material (approximately 382 m^3 (500 yd^3) was mechanically excavated from a Great Lakes CDF using a large backhoe. Unit costs for this effort were approximately \$2.25/yd^3. The effort required approximately one-half day in the field to complete.

Separation/Dewatering. Overall project costs expressed on a unit basis ranged from \$18 to \$410/yd^3 for 10 case studies reported in the literature, utilizing separation and mechanical dewatering (Wisconsin Department of Natural Resources 2002; Sevenson Environmental Services 2002a, 2002b, 2002c; USEPA 2002a, 2002b, 2002c; USEPA 1992). Project costs appear to have been influenced by level of contamination, total project volume, offsite transportation and disposal costs, real estate and permitting costs, water treatment requirements, and public relations efforts. A range of \$18 to \$60/yd^3 appears to be representative of the separation and dewatering cost component, when isolated from other project costs, for project volumes of 191,139-573,416 m^3 (250,000-750,000 yd^3). The lowest unit cost is exclusive of a mobilization/demobilization cost. Unit costs for smaller volume projects would likely be higher.

Transportation/Off-site Disposal. Transportation and offsite disposal costs may be on a unit volume distance or a unit weight distance basis. River transportation costs reported in the northeastern region ranged from \$0.65/cubic yard mile to \$1.00/cubic yard mile, with the higher costs reflecting distances greater than 8 river miles. Overland transport over distances up to

1,067 m (3,500 ft) ranged from $1.25 to $2.50/cubic yard mile, with the lower cost reflecting volumes greater than 7,646 m^3 (10,000 yd^3). Transport by truck, or truck/rail combination, ranged from $80- $110/ton, with direct rail costs being lowest, but access dependent. Offsite disposal costs ranged from $50 to $150/ton (U.S. FY 2000), with the highest disposal costs including the transportation costs.

SUMMARY: The economic viability of separation as a dredged material management alternative is largely dependent upon the benefits to be derived by reducing the volume or the weight of material requiring onsite or offsite disposal. Preliminary estimates of recoverable volume can be made on the basis of bench-scale sediment characterization data. More quantitative estimates of potential volume recovery can be obtained by calculating a fractional bulking factor based on material properties in situ and following bench- or pilot-scale process testing. The benefit of this volume reduction can be determined by calculating an average annual cost for the base condition, and comparing the average annual cost for the selected separation alternative. This information will be useful in making planning level decisions, and determining what alternatives merit detailed cost analysis. Among cost-comparable alternatives, intangible benefits may also be factored in.

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APPENDIX A
BULKING FACTOR DERIVATION

Define in situ volume V_{T_i} as follows:

$$V_{T_i} = V_{s_i} + V_{F_i} + V_{V_i} \tag{A1}$$

where

V_{s_i} = volume sand, in situ or initial

V_{F_i} = volume fines, in situ or initial

V_{V_i} = volume voids, in situ or initial

Define dewatered sediment volume V_{T_f} (final total volume) as follows:

$$V_{T_f} = (1 - x_v) V_{s_i} + V_{F_i} + V_{V_f} \tag{A2}$$

where

x_v = efficiency of sand removal, by volume

V_{V_f} = volume voids, final

Define the overall bulking factor as

$$b = \frac{V_{T_f}}{V_{T_i}} \tag{A3}$$

By definition, total or wet density is

$$\rho_t = \frac{M_T}{V_T} \tag{A4}$$

where

M_T = total mass of water and solids

V_T = total volume of voids and solids
= total volume of water and solids, at 100 percent saturation ($V_{voids} = V_{water}$)

Then:

$$b = \frac{V_{T_F}}{V_{T_i}} = \frac{\dfrac{M_{T_f}}{\rho_{t_f}}}{\dfrac{M_{T_i}}{\rho_{t_i}}} = \frac{\dfrac{(1-x_m)\,M_{S_i} + M_{F_i} + M_{w_f}}{\rho_{t_f}}}{\dfrac{M_{S_i} + M_{F_i} + M_{w_i}}{\rho_{t_f}}} \qquad \text{(A5)}$$

where

M_{T_f} = total mass of water and solids, final or dewatered condition

ρ_{t_f} = total density, final or dewatered condition

M_{T_i} = total mass of water and solids, in situ or initial

ρ_{t_i} = total density, in situ or initial

x_m = sand removal efficiency by mass

M_{S_i} = mass sand, in situ or initial

M_{F_i} = mass fines, in situ or initial

M_{w_f} = mass of water, final or dewatered condition

M_{w_i} = mass water, in situ or initial

Percent water content w is defined as

$$w = \frac{M_w}{M_{solids}}(100) \qquad \text{(A6)}$$

M_{w_i} can therefore be described as

$$M_{w_i} = \frac{w_i}{100} M_{solids_i} = \frac{w_i}{100}\left(M_{S_i} + M_{F_i}\right) \qquad \text{(A7)}$$

where w_i is water content as a decimal.

M_{w_f} can be described as:

$$M_{w_f} = \frac{w_f}{100} M_{solids_f} = \frac{w_f}{100}\left[(1-x_m)M_{S_i} + M_{F_i}\right] \qquad \text{(A8)}$$

where w_f is water content as a decimal.

Substituting:

$$b = \frac{\dfrac{\left(1 - x_m\right) M_{S_i} + M_{F_i} + \dfrac{w_f}{100}\left[\left(1 - x_m\right) M_{S_i} + M_{F_i}\right]}{\rho_{t_f}}}{\dfrac{M_{S_i} + M_{F_i} + \dfrac{w_i}{100}\left(M_{S_i} + M_{F_i}\right)}{\rho_{t_i}}} \tag{A9}$$

Simplifying yields:

$$b = \frac{\left(1 + w_f\right)\left[\left(1 - x_m\right) M_{S_i} + M_{F_i}\right]\rho_{t_i}}{\left(1 + w_i\right)\left(M_{S_i} + M_{F_i}\right)\rho_{t_f}} \tag{A10}$$

Recall that

$$b = \frac{V_{T_f}}{V_{T_i}} \tag{All}$$

An estimate of the disposal volume following processing can therefore be obtained based on the hydrographic survey and projected dredging depths V_{T_i}, and the bulking factor derived by measuring the initial and final water content, sand and fine mass, and wet density, of representative samples, thus:

$$V_{T_f} = b V_{T_i} \tag{A12}$$

The net volume recovery is then

$$\Delta V = V_{T_i} - V_{T_f} \tag{A13}$$

APPENDIX B
CDF CONSTRUCTION COSTS

Great Lakes Confined Disposal Facilities Constructed under Section 123, PL 91-611

Name/Location	State	Type*	Year Built	CCI_{yr}/CCI_{2000}	CCI_{2000}/CCI_{yr}	Capacity, yd^3	Planned Uses	Const. Cost	Present $ Const. Cost.	Present $ cost/yd^3
Cleveland Harbor Dike 12	OH	L	1974	0.3238	3.088	2760000	Waterfront Dev.	$6,800,000	$20,999,208	$7.61
Huron Harbor	OH	L	1975	0.3546	2.820	2600000	Small Boat Harbor	$6,400,000	$18,048,463	$6.94
Toledo Harbor site 3	OH	L	1976	0.3849	2.598	11100000	Port Development	$18,400,000	$47,804,748	$4.31
Buffalo harbor Dike 4	NY	L	1977	0.4130	2.422	6900000	Wildlife Area	$15,400,000	$37,292,391	$5.40
Lorain Harbor	OH	L	1977	0.4130	2.422	1850000	Small Boat Harbor	$7,900,000	$19,130,512	$10.34
Erie Harbor	PA	L	1979	0.4814	2.077	420000	Industrial Dev.	$400,000	$830,902	$1.98
Cleveland harbor Dike 14	OH	L	1979	0.4814	2.077	6130000	Recreation/Park	$28,300,000	$58,786,347	$9.59
Michigan City	IN	U	1978	0.4450	2.247	50000	Recreation/Park	$300,000	$674,135	$13.48
Chicago Area	IL	L	1984	0.6646	1.505	1300000	Marina Expansion	$7,800,000	$11,735,745	$9.03
Grand haven Harbor	MI	U	1974	0.3238	3.088	310000	Public Use	$433,000	$1,337,155	$4.31
Milwaukee Harbor	WI	L	1975	0.3546	2.820	1600000	Expansion	$5,963,000	$16,816,091	$10.51
Dickinson Island	MI	I	1975	0.3546	2.820	2000000	Wildlife Area	$5,072,000	$14,303,407	$7.15
Manitowoc Harbor	WI	L	1975	0.3546	2.820	800000	Land Use Dev.	$4,147,000	$11,694,840	$14.62
Kenosha Harbor	WI	L	1975	0.3546	2.820	750000	Public Use	$8,270,000	$23,321,998	$31.10
Bolles Harbor	MI	L	1978	0.4450	2.247	335000	marina expansion	$972,000	$2,184,199	$6.52
Saginaw Bay	MI	I	1978	0.4450	2.247	10000000	Wildlife Area	$14,844,000	$33,356,222	$3.34
Holland Bbr-Riverview Site	MI	L	1978	0.4450	2.247	120000	Recreation/Park	$1,583,000	$3,557,188	$29.64
Holland Bbr-Windmill Site	MI	I	1978	0.4450	2.247	160000	Recreation/Park	$1,654,000	$3,716,733	$23.23
Sebewaing Harbor	MI	U	1979	0.4814	2.077	84000	Airport Expansion	$1,300,000	$2,700,433	$32.15
Duluth Harbor Erie Pier	MN	L	1979	0.4814	2.077	1000000	Recreational Area	$1,558,000	$3,236,365	$3.24
Pte Moouille	MI	I	1981	0.5667	1.765	18000000	Wildlife Area/Marsh	$55,856,000	$98,565,694	$5.48
Green Bay Harbor	WI	I	1979	0.4814	2.077	1200000	Recreational	$5,565,000	$11,559,930	$9.63
Kewaunee Harbor	WI	L	1982	0.6132	1.631	500000	Recreational	$2,017,000	$3,289,424	$6.58
Frankfort Harbor	MI	U	1982	0.6132	1.631	74000		$800,000	$1,304,680	$17.63
Inland Route	MI	U	1982	0.6132	1.631	195000	Wildlife Area	$176,000	$287,030	$1.47
Monroe Harbor	MI	L	1983	0.6518	1.534	4300000	State Park	$38,380,000	$58,882,056	$13.69
Keweenaw Waterway	MI	U	1987	0.7063	1.416	308000		$941,000	$1,332,265	$4.33
Clinton River	MI	U	1989	0.7398	1.352	370000	Recreational Area	$2,618,000	$3,538,696	$9.56
Cleveland Harbor Dike 10	OH	L	1970	0.2214	4.517	1000000	Waterfront Dev.			
Cleveland Harbor Dike 10B	OH	L	1998	0.9490	1.054	3840000	Airport	$32,900,000	$34,667,264	$9.03
Small Boat Harbor/Buffalo	NY	L	1968	0.1852	5.401	1500000	Small Boat Harbor	$500,000	$2,700,433	$1.80
Times Beach/Buffalo	NY	L	1972	0.2810	3.558	1500000	Wildlife Area	$500,000	$1,779,236	$1.19
Grassy Island (Isl 18)/Toledo	OH	I	1977	0.4130	2.422	5000000	None	$5,000,000	$12,107,919	$2.42
Toledo Harbor Site 3 Ext	OH	L	1994	0.8669	1.153	5300000		$4,800,000	$5,536,686	$1.04
Bayport/Green Bay	WI	L	1965	0.1557	6.424	650000	City Landfill			
Clinton River/Fisheries Site	MI	L	1979	0.4814	2.077	21000	Recreational Area			
Grassy Island/Detroit River	MI	I	1960	0.1321	7.570	4320000	Wildlife Area	$747,150	$5,656,216	$1.31
Harsen's Island/St Clair riv.	MI	U	1975	0.3546	2.820	100000	Wildlife Area			
Kawkawlin River	MI	U								
Monroe Edison	MI	U					Detroit Edison			
Port Sanilac	MI	U	1979	0.4814	2.077	143300	Municipal Landfill			
Verplank/Grand Haven Harbor	MI	U	1974	0.3238	3.088	134000	Parking Lot			
Whirlpool/St. Joseph Harbor	MI	U	1978	0.4450	2.247	25000	Transfer Site	$638,076	1,433,832.16	$57.35
Malleable/St. Joseph Harbor	MI	U	1978	0.4450	2.247	35000				
Middleground/Saginaw River	MI	L	1978	0.4450	2.247	150000	Recreation Area			

* U - Upland, I - In water, Island, L- In water, Adjacent to land or breakwater

Construction Cost Index from ENR (website)

ANNUAL AVERAGE								
1908	97	**1931**	181	**1954**	628	**1977**	2576	
1909	91	**1932**	157	**1955**	660	**1978**	2776	
1910	96	**1933**	170	**1956**	692	**1979**	3003	
1911	93	**1934**	198	**1957**	724	**1980**	3237	
1912	91	**1935**	196	**1958**	759	**1981**	3535	
1913	100	**1936**	206	**1959**	797	**1982**	3825	
1914	89	**1937**	235	**1960**	824	**1983**	4066	
1915	93	**1938**	236	**1961**	847	**1984**	4146	
1916	130	**1939**	236	**1962**	872	**1985**	4195	
1917	181	**1940**	242	**1963**	901	**1986**	4295	
1918	189	**1941**	258	**1964**	936	**1987**	4406	
1919	198	**1942**	276	**1965**	971	**1988**	4519	
1920	251	**1943**	290	**1966**	1019	**1989**	4615	
1921	202	**1944**	299	**1967**	1074	**1990**	4732	
1922	174	**1945**	308	**1968**	1155	**1991**	4835	
1923	214	**1946**	346	**1969**	1269	**1992**	4985	
1924	215	**1947**	413	**1970**	1381	**1993**	5210	
1925	207	**1948**	461	**1971**	1581	**1994**	5408	
1926	208	**1949**	477	**1972**	1753	**1995**	5471	
1927	206	**1950**	510	**1973**	1895	**1996**	5620	
1928	207	**1951**	543	**1974**	2020	**1997**	5825	
1929	207	**1952**	569	**1975**	2212	**1998**	5920	
1930	203	**1953**	600	**1976**	2401	**1999**	6060	
						2000	6238	(June)

APPENDIX C
PROJECT EXAMPLES[1]

Example 1

The first example compares costs for the following six dredging and disposal alternatives for a one-time project, such as a remediation action, with a 2-year period of analysis:

1. Hydraulic dredging, CDF disposal
2. Hydraulic dredging, sand separation, CDF disposal of fines
3. Hydraulic dredging, sand separation, CDF placement of dewatered fines
4. Hydraulic dredging, sand separation, dewatering and offsite disposal of fines
5. Mechanical dredging, CDF disposal
6. Mechanical dredging, offsite disposal

Dredging costs are applied to in situ project volume. Separation, dewatering, and transportation costs are applied to processed volumes or weights. Unit CDF construction costs are based on sediment storage requirements, and are adjusted upward for alternatives requiring higher dikes to provide freeboard and ponding volume. For each alternative, a total project cost is calculated, including dredging, processing, transport, and disposal costs. These costs are then converted to a project cost/year, based on the duration of the dredging (Tables C1, C3, C5,…C11). Costs for CDF construction and closure capping are also calculated. Interest during construction is then calculated for each alternative and applied to the annual project costs, plus CDF construction and capping costs, which are added to the annual project costs in the respective years in which they occur (Tables C2, C4,…C12). This gives a Total Financial Investment cost for each alternative, which is the basis for the economic comparison of each alternative. The least-cost CDF disposal alternative without separation (mechanical dredging, CDF disposal) is the base condition. The results of this analysis indicate that, for the assumptions made, a negative benefit is derived from the use of separation, where mechanical dredging and CDF disposal is an alternative (Table C13). A positive benefit is seen where offsite disposal is required. For separation alternatives, beneficial use of sand with no associated transport or disposal costs is assumed. No real estate acquisition is included in CDF construction costs, as the site is normally provided by the sponsor and is not a government expense.

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1 To convert measurements given in tons in these examples to kilograms, multiply by 907. To convert measurements given in cubic yards to cubic meters, multiply by 0.7645.

Table C1
Alternative 1: Hydraulic Dredging, CDF Disposal, Engineering Costs

	Engineering Costs, Alternative 1							
Cost Item	**$/ton**	**$/cy**	**Total Tons**	**tons/ yr**	**Total cy**	**cy/yr**	**Total $**	**$/yr**
Hyd Dredging Cost[1]		$4		0	225,000	112,500	900,000	$450,000
Mech Dredging Cost[1]		$7		0		0		$0
Mobilization/demobilization				0		0	1,000,000	$500,000
Separation[1]		$15		0		0		$0
Separation/Dewatering[1]		$60		0		0		$0
Transportation[2]	$110			0		0		$0
Disposal[2]	$50			0		0		$0
Revenues from sale		1		0		0		0
Total:						**0**	**$1,900,000**	**$950,000**
CDF Construction[3]		$4			602,165			$2,408,660
Capping		$2			172,888			$345,776

[1] Based on in situ volumes or weights.
[2] Based on processed volumes or weights.
[3] Based on sediment storage volume. Estimated unit costs are based on literature values for similar size CDFs, with upward adjustments made where freeboard and ponding are required.

Table C2
Alternative 1: Hydraulic Dredging, CDF Disposal, Financial Costs
(Interest Rate = 0.06375)

	2001	**2002**	**2003**
Cubic Yards	0	112,500	112,500
$/yr	$2,408,660	$950,000	$1,295,776
IDC (interest during construction)	$490,647	$124,986	$82,606
Cost/Year	$2,899,307	$1,074,986	$1,378,382
Total Financial Investment:			**$5,352,675**

(green)	CDF Construction included here if completely precedes dredging.
(yellow)	CDF and first-year dredging included here if they will both occur in the first year.
(orange)	Includes final-year capping costs.

Table C3
Alternative 2: Hydraulic Dredging, Sand Separation, CDF Disposal of Fines, Engineering Costs

	Engineering Costs, Alternative 2							
Cost Item	**$/ton**	**$/cy**	**Total Tons**	**tons/ yr**	**Total cy**	**cy/yr**	**Total $**	**$/yr**
Hyd Dredging Cost[1]		$4		0	225,000	112,500	900,000	$450,000
Mech Dredging Cost[1]		$7		0		0		$0
Mobilization/demobilization				0		0	1,000,000	$500,000
Separation[1]		$15		0	225,000	112,500	3,375,000	$1,687,500
Separation/Dewatering[1]		$60		0		0		$0
Transportation[2]	$110			0		0		$0
Disposal[2]	$50			0		0		$0
Revenues from sale		-1		0	33,613	16,807	-33,613	-16,806.5
Total:							**$5,241,387**	$2,620,694
CDF Construction[3]		$4			538,753			$2,155,012
Capping		$2			153,244			$306,488

[1] Based on in situ volumes or weights.
[2] Based on processed volumes or weights.
[3] Based on sediment storage volume. Estimated unit costs are based on literature values for similar size CDFs, with upward adjustments made where freeboard and ponding are required.

Table C4
Alternative 2: Hydraulic Dredging, Sand Separation, CDF Disposal of Fines, Financial Costs (Interest Rate = 0.06375)

	2001	**2002**	**2003**
Cubic Yards	0	112,500	112,500
$/yr	$2,155,012	$2,620,694	$2,927,182
IDC (interest during construction)	$438,979	$344,789	$186,608
Cost/Year	$2,593,991	$2,965,483	$3,113,789
Total Financial Investment:			**$8,673,263**

(green)	CDF Construction included here if completely precedes dredging.
(yellow)	CDF and first-year dredging included here if they will both occur in the first year.
(orange)	Includes final-year capping costs.

Table C5
Alternative 3: Hydraulic Dredging, Sand Separation, Dewatering and CDF Fines Disposal, Engineering Costs

	Engineering Costs, Alternative 3							
Cost Item	**$/ton**	**$/cy**	**Total Tons**	**tons/ yr**	**Total cy**	**cy/yr**	**Total $**	**$/yr**
Hyd Dredging Cost[1]		$4		0	225,000	112,500	900,000	$450,000
Mech Dredging Cost[1]		$7		0		0		$0
Mobilization/demobilization				0		0	1,000,000	$500,000
Separation[1]		$15		0		0		$0
Separation/Dewatering[1]		$60		0	225,000	112,500	13,500,000	$6,750,000
Transportation[2]	$110			0		0		$0
Disposal[2]	$50			0		0		$0
Revenues from sale		-1		0	33,613	-16,807	-33,613	-16,805.5
Total:							**$15,366,387**	$7,683,194
CDF Construction[3]		$6			100,158			$600,948
Capping	no freeboard or ponding volume							$306,488

[1] Based on in situ volumes or weights.
[2] Based on processed volumes or weights.
[3] Based on sediment storage volume. Estimated unit costs are based on literature values for similar size CDFs, with upward adjustments made where freeboard and ponding are required.

Table C6
Alternative 3: Hydraulic Dredging, Sand Separation, Dewatering and CDF Fines Disposal, Financial Costs (Interest Rate = 0.06375)

	2001	**2002**	**2003**
Cubic Yards	0	112,500	112,500
$/yr	$600,948	$7,683,194	$7,989,682
IDC (interest during construction)	$122,414	$1,010,832	$509,342
Cost/Year	$723,362	$8,694,026	$8,499,024
Total Financial Investment:			**$17,916,411**

Green	CDF Construction included here if completely precedes dredging.
Yellow	CDF and first-year dredging included here if they will both occur in the first year.
Orange	Although there is no freeboard or ponding volume that must be filled, it was assumed that some form of cap would be required at closure, and a representative value was included based on amount calculated for other sites.

Table C7
Alternative 4: Hydraulic Dredging, Sand Separation, Dewatering and Offsite Disposal of Fines, Engineering Costs

	Engineering Costs, Alternative 4							
Cost Item	**$/ton**	**$/cy**	**Total Tons**	**tons/ yr**	**Total cy**	**cy/yr**	**Total $**	**$/yr**
Hyd Dredging Cost[1]		$4		0	225,000	112,500	900,000	$450,000
Mech Dredging Cost[1]		$7		0		0		$0
Mobilization/demobilization				0		0	1,000,000	$500,000
Separation[1]		$15		0		0		$0
Separation/Dewatering[1]		$60		0	225,000	112,500	13,500,000	$6,750,000
Transportation[2]	$110		137,392	68,696		0	15,113,120	$7,556,560
Disposal[2]	$50		137,392	68,696		0	6,869,600	$3,434,800
Revenues from sale		-1			33,613	16,807	-33,613	-16,806.5
Total:							**$37,349,107**	$18,674,554
CDF Construction[3]		$6			0			$0
Capping		$2			0			$0

[1] Based on in situ volumes or weights.
[2] Based on processed volumes or weights.
[3] Based on sediment storage volume. Estimated unit costs are based on literature values for similar size CDFs, with upward adjustments made where freeboard and ponding are required.

Table C8
Alternative 4: Hydraulic Dredging, Sand Separation, Dewatering and Offsite Disposal of Fines, Financial Costs (Interest Rate = 0.06375)

	2001	**2002**	**2003**
Cubic Yards	0	112,500	112,500
$/yr	$0	$18,674,554	$18,674,554
IDC (interest during construction)	$0	$2,456,900	$1,190,503
Cost/Year	$0	$21,131,454	$19,865,056
Total Financial Investment:			**$40,996,510**

(green)	CDF Construction included here if completely precedes dredging.
(yellow)	CDF and first-year dredging included here if they will both occur in the first year.

Table C9
Alternative 5: Mechanical Dredging, CDF Disposal, Engineering Costs

	Engineering Costs, Alternative 5							
Cost Item	**$/ton**	**$/cy**	**Total Tons**	**tons/ yr**	**Total cy**	**cy/yr**	**Total $**	**$/yr**
Hyd Dredging Cost[1]		$4		0		0	0	$0
Mech Dredging Cost[1]		$7		0	225,000	112,500		$787,500
Mobilization/demobilization				0		0	1,000,000	$500,000
Separation[1]		$15		0		0		$0
Separation/Dewatering[1]		$60		0		0		$0
Transportation[2]	$110			0		0		$0
Disposal[2]	$50			0		0		$0
Revenues from sale		1		0		0		$0
Total:							$1,000,000	**$1,287,500**
CDF Construction[3]		$5			317,673			$1,588,367
Capping		$2			70,173			$140,347

[1] Based on in situ volumes or weights.
[2] Based on processed volumes or weights.
[3] Based on sediment storage volume. Estimated unit costs are based on literature values for similar size CDFs, with upward adjustments made where freeboard and ponding are required.

Table C10
Alternative 5: Mechanical Dredging, CDF Disposal, Financial Costs
(Interest Rate = 0.06375)

	2001	**2002**	**2003**
Cubic Yards	0	112,500	112,500
$/yr	$1,588,367	$1,287,500	$1,427,847
IDC (interest during construction)	$323,552	$169,389	$91,025
Cost/Year	$1,911,920	$1,456,889	$1,518,872
Total Financial Investment:			**$4,887,681**

(green)	CDF Construction included here if completely precedes dredging.
(yellow)	CDF and first-year dredging included here if they will both occur in the first year.
(orange)	Includes final-year capping costs.

Table C11
Alternative 6: Mechanical Dredging, Offsite Disposal, Engineering Costs

	Engineering Costs, Alternative 6							
Cost Item	**$/ton**	**$/cy**	**Total Tons**	**tons/ yr**	**Total cy**	**cy/yr**	**Total $**	**$/yr**
Hyd Dredging Cost[1]		$4		0		0	0	$0
Mech Dredging Cost[1]		$7		0	225,000	112,500		$787,500
Mobilization/demobilization				0		0	1,000,000	$500,000
Separation[1]		$15		0		0		$0
Separation/Dewatering[1]		$60		0		0		$0
Transportation[2]	$110		287,943	143,972		0	31,673,730	$15,836,865
Disposal[2]	$50		287,943	143,972		0	14,397,150	$7,198,575
Revenues from sale		1		0		0		0
Total:							**$47,070,880**	$24,322,940
CDF Construction[3]		$5			0			$0
Capping		$2			0			$30

[1] Based on in situ volumes or weights.
[2] Based on processed volumes or weights.
[3] Based on sediment storage volume. Estimated unit costs are based on literature values for similar size CDFs, with upward adjustments made where freeboard and ponding are required.

Table C12
Alternative 6: Mechanical Dredging, Offsite Disposal, Financial Costs
(Interest Rate = 0.06375)

	2001	**2002**	**2003**
Cubic Yards	0	112,500	112,500
$/yr	$0	$24,322,940	$24,322,940
IDC (interest during construction)	$0	$3,200,025	$1,550,587
Cost/Year	$0	$27,522,965	$25,873,527
Total Financial Investment:			**$53,396,492**

(green)	CDF Construction included here if completely precedes dredging.
(yellow)	CDF and first-year dredging included here if they will both occur in the first year.

Table C13
Identification of Base Plan and Calculation of Separation Benefit

Compare Alternatives		
Alternative	**Initial Investment**	**Alternative Description**
Initial Construction & Maintenance		
1	$5,352,675	Hydraulic dredging, CDF disposal
2	$8,673,263	Hydraulic dredging, sand separation, CDF disposal of fines
3	$17,916,411	Hydraulic dredging, sand separation, dewatering of fines and placement in CDF
4	$40,996,510	Hydraulic dredging, sand separation, dewatering of fines, and offsite disposal of fines
5	$4,887,681	Mechanical dredging and placement in a CDF
6	$53,396,492	Mechanical dredging and offsite disposal
Assuming all alternatives are available		
Base plan	$4,887,681	Least-cost alternative without separation is base plan
Separation	$8,673,263	Least-cost separation alternative is selected for comparison
Benefit to separation	**-$3,785,582**	
Assuming offsite disposal is required		
Base plan	$53,396,492	Mechanical dredging with offsite disposal is base plan
Separation	$40,996,510	Least-cost separation alternative with offsite disposal is selected for comparison
Benefit to separation	**$12,399,982**	

Example 2

The second example assumes a 30-year period of analysis and available CDF storage capacity of 1,800,000 yd^3 at the inception of the period of analysis. Capacity of the CDF constructed in the out years of the project is assumed to accommodate the material produced from the time of filling of the old CDF to the end of the period of analysis. Rate of capacity consumption is based on solids volume at the end of each disposal operation, neglecting consolidation. Capping material volume is assumed to equal freeboard and ponding volume. (Neglecting material consolidation results in a conservative overestimate of storage capacity required and an underestimate of capping material required. Programs are available to estimate time-dependent consolidation of dredged material and fill, but these simplifying assumptions facilitate planning level cost comparisons. A more rigorous evaluation of consolidation and effect on the CDF life cycle would be required for detailed cost estimating.) In situ sediment volume for the construction phase was assumed to be 775,000 yd^3 with 40 percent fines by weight. Maintenance dredging was assumed to take place every 3 years, with an in situ volume of 75,000 yd^3. A 16-in. (0.4-m) hydraulic dredge is assumed for hydraulic dredging scenarios, and calculation of sediment storage requirements using SETTLE. A bulking factor of 1.1 (applied to in situ volume) was used to estimate sediment storage requirements for mechanical dredging alternatives. An annual cost to maintain the CDF (facility maintenance) of $20,000 was assumed for all alternatives. The following alternatives were considered:

1. Hydraulic dredging, CDF disposal (Tables C14-C16).
2. Hydraulic dredging, sand separation, CDF disposal of fine residuals (Tables C17-C19).
3. Hydraulic dredging, sand separation, CDF disposal of dewatered fine residuals (Tables C20-C22).

As for the first example, no cost was assumed to be incurred for disposal or transportation of sand produced for beneficial use. No real estate acquisition costs are considered.

Comparison of average annual costs for the three alternatives reveals that Alternative 1 (Table C23) has the lowest average annual cost ($1,785,100), with the CDF being replaced after two maintenance dredging cycles. Alternative 2 (Table C24) is next at $1,898,300, with the CDF being replaced after 14 maintenance dredging cycles (beyond the end of the period of analysis). Alternative 3 (Table C25) has the highest annual cost ($2,776,000), but the CDF does not need to be replaced for 49 maintenance dredging cycles (beyond the end of the period of analysis). The base alternative may therefore be different (Alternative 2 or 3, rather than Alternative 1) for a longer period of analysis that captures the life extension of the CDF (Table C26). As the period of analysis increases, however, the effect of consolidation on rate of capacity consumption becomes more important and should be factored into the analysis.

Table C14
Alternative 1: Hydraulic Dredging and Conventional Disposal in an Existing CDF, Engineering Costs

	Engineering Costs, Alternative 1								
Cost Item	**$/ton**	**$/cy**	**Total tons**	**tons/ yr**	**Total cy**	**Dura-tion yr**	**cy/yr**	**Total $**	**$/yr**
Hyd Dredging Cost[1]		$4		0	775,000	2	387,500	$3,100,000	$1,550,000
Mech Dredging Cost[1]		$7		0			0		$0
Mob/Demob				0		2	0	$1,000,000	$500,000
Separation[1]		$15		0			0		$0
Separation/Dewatering[1]		$25		0			0		$0
Transportation[2]	$110			0			0		$0
Disposal[2]	$50			0			0		$0
Revenues from sale		1		0			0		$0
Total:								**$4,100,000**	**$2,050,000**
CDF Construction		$6			0				$0
Capping		$2			619,830				$1,239,660 1,800,000

[1] Based on in situ volumes or weights.
[2] Based on processed volumes or weights.

Available Storage Capacity (cy)	1,800,000
Storage Capacity Consumed (cy)	1,399,016
Remaining Storage Capacity (cy)	400,984

Table C15
Alternative 1: Hydraulic Dredging and Conventional Disposal in an Existing CDF, Financial Costs (Interest Rate = 0.06375)

	2001	2002	2003
Cubic Yards	0	112,500	112,500
$/yr		$2,050,000	$2,050,000
IDC (interest during construction)	$0	$269,706	$130,688
Cost/Year	$0	$2,319,706	$2,180,688
Total Financial Investment:			**$4,500,394**

(green)	CDF Construction included here if completely precedes dredging.
(yellow)	CDF and first-year dredging included here if they will both occur in the first year.

Table C16
Alternative 1: Hydraulic Dredging and Conventional Disposal in an Existing CDF, Maintenance Dredging Engineering Costs

	Maintenance Dredging Engineering Costs, Alternative 1				
Cost Item	**$/ton**	**$/cy**	**tons/yr**	**cy/3 yr**	**$/yr**
Hyd Dredging Cost[1]		$4	0	75,000	$350,000
Mech Dredging Cost[1]		$7	0	0	$0
Mob/Demob			0	0	$500,000
Separation[1]		$15	0	0	$0
Separation/Dewatering[1]		$25	0	0	$0
Transportation[2]	$110		0	0	$0
Disposal[2]	$50		0	0	$0
Revenues from sale		1	0	0	$0
Total:					**$800,000**
Additional Cost Items:					
Annual Facility Maintenance					$20,000
Storage capacity consumed cy/3 yr				143,087	
Available storage capacity at first cycle				400,984	
Cycles to replacement of existing CDF yr				2.80	
Number of maintenance cycles completed				2	
Number of maintenance cycles remaining				8	
Volume CDF required to accommodate remainder of dredging for period of analysis, plus freeboard and ponding					
In situ sediment volume total cy				600,000	
Freeboard and ponding (1 cycle requirement) cy				704,218	
Total volume cy				1,304,218	
				cy	**Total Estimated Costs**
CDF Construction cost		$18			$23,475,924
Capping Old CDF (after 2 cylces)		$2	cap volume	800,000	$1,600,000
Capping New CDF		$2			1,408,436

[1] Based on in situ volumes or weights.
[2] Based on processed volumes or weights.

Table C17
Alternative 2: Hydraulic Dredging, Sand Separation, CDF Disposal of Fines, Engineering Costs

	Engineering Costs, Alternative 2								
Cost Item	**$/ton**	**$/cy**	**Total tons**	**tons/ yr**	**Total cy**	**Dura-tion yr**	**cy/yr**	**Total $**	**$/yr**
Hyd Dredging Cost[1]		$4		0	775,000	2	387,500	$3,100,000	$1,550,000
Mech Dredging Cost[1]		$7		0			0		$0
Mob/Demob				0		2	0	$1,000,000	$500,000
Separation[1]		$15		0	775,000		387,500	$11,625,000	$5,812,500
Separation/Dewatering[1]		$25		0			0		$0
Transportation[2]	$110			0			0		$0
Disposal[2]	$50			0			0		$0
Revenues from sale		-1		0	254,700		127,350		-127,350
Total:								**$15,725,000**	**$7,735,150**
CDF Construction		$6			0				$0
Capping		$2			0				$0

[1] Based on in situ volumes or weights.
[2] Based on processed volumes or weights.

Available Storage Capacity (cy)	1,800,000
Storage Capacity Consumed (cy)	759,255
Remaining Storage Capacity (cy)	1,040,745

Table C18
Alternative 2: Hydraulic Dredging, Sand Separation, CDF Disposal of Fines, Financial Costs (Interest Rate = 0.06375)

	2001	2002	2003
Cubic Yards	0	387,500	387,500
$/yr		$7,735,150	$7,735,150
IDC (interest during construction)	$0	$1,017,668	$493,116
Cost/Year	$0	$8,752,818	$8,228,266
Total Financial Investment:			**$16,981,084**

(green)	CDF Construction included here if completely precedes dredging.
(yellow)	CDF and first-year dredging included here if they will both occur in the first year.

Table C19
Alternative 2: Hydraulic Dredging, Sand Separation, CDF Disposal of Fines, Maintenance Dredging Engineering Costs

	Maintenance Dredging Engineering Costs, Alternative 2				
Cost Item	**$/ton**	**$/cy**	**tons/yr**	**cy/3 yr**	**$/yr**
Hyd Dredging Cost[1]		$4	0	75,000	$300,000
Mech Dredging Cost[1]		$7	0	0	$0
Mob/Demob			0	0	$500,000
Separation[1]		$15	0	75,000	$1,125,000
Separation/Dewatering[1]		$25	0	0	$0
Transportation[2]	$110		0	0	$0
Disposal[2]	$50		0	0	$0
Revenues from sale		-1	0	24,648	-24,648
Total:					**$1,900,352**
Additional Cost Items:					
Annual Facility Maintenance					$20,000
Storage capacity consumed cy/3 yr				73,477	
Available storage capacity at first cycle				1,040,745	
Cycles to replacement of existing CDF yr				14.16	
Number of maintenance cycles completed				10	
(There are only 10 cycles in period of analysis)					
Number of maintenance cycles remaining				0	
Volume CDF required to accommodate remainder of dredging for period of analysis, plus freeboard and ponding					
In situ sediment volume total cy				0	
Freeboard and ponding (1 cycle requirement) cy				0	
Total volume cy				0	
		$/cy			**Total Estimated Costs**
CDF Construction Cost		$18			$0
Capping Old CDF (after 14 cylces)		$2			$0[3]
Capping New CDF		$2			$0

[1] Based on in situ volumes or weights.
[2] Based on processed volumes or weights.
[3] Closure of existing CDF falls ouside period of analysis.

Table C20
Alternative 3: Hydraulic Dredging, Sand Separation, Dewatering and CDF Placement of Fines, Engineering Costs

	Engineering Costs, Alternative 3								
Cost Item	**$/ton**	**$/cy**	**Total tons**	**tons/ yr**	**Total cy**	**Dura-tion yr**	**cy/yr**	**Total $**	**$/yr**
Hyd Dredging Cost[1]		$4		0	775,000	2	387,500	$3,100,000	$1,550,000
Mech Dredging Cost[1]		$7		0			0		$0
Mob/Demob				0		2	0	$1,000,000	$500,000
Separation[1]		$15		0			0		$0
Separation/Dewatering[1]		$25		0	775,000		387,500		$9,687,500
Transportation[2]	$110			0			0		$0
Disposal[2]	$50			0			0		$0
Revenues from sale		-1		0	254,700		127,350		-127,350
Total:								**$4,100,000**	$11,610,150
CDF Construction		$6			0				$0
Capping		$2			0				$0

[1] Based on in situ volumes or weights.
[2] Based on processed volumes or weights.

Available Storage Capacity (cy)	1,800,000
Storage Capacity Consumed (cy)	309,863
Remaining Storage Capacity (cy)	1,490,137

Table C21
Alternative 3: Hydraulic Dredging, Sand Separation, Dewatering and CDF Placement of Fines, Financial Costs (Interest Rate = 0.06375)

	2001	**2002**	**2003**
Cubic Yards	0	387,500	387,500
$/yr		$11,610,150	$11,610,150
IDC (interest during construction)	$0	$1,527,479	$740,147
Cost/Year	$0	$13,137,629	$12,350,297
Total Financial Investment:			**$25,487,926**

(green)	CDF Construction included here if completely precedes dredging.
(yellow)	CDF and first-year dredging included here if they will both occur in the first year.

Table C22
Alternative 3: Hydraulic Dredging, Sand Separation, Dewatering and CDF Placement of Fines, Maintenance Dredging Engineering Costs

	Maintenance Dredging Engineering Costs, Alternative 3				
Cost Item	**$/ton**	**$/cy**	**tons/yr**	**cy/3 yr**	**$/yr**
Hyd Dredging Cost[1]		$4	0	75,000	$300,000
Mech Dredging Cost[1]		$7	0	0	$0
Mob/Demob			0	0	$500,000
Separation[1]		$15	0	0	$0
Separation/Dewatering[1]		$25	0	75,000	$1,875,000
Transportation[2]	$110		0	0	$0
Disposal[2]	$50		0	0	$0
Revenues from sale		-1	0	24,648	-24,648
Total:					**$2,650,352**
Additional Cost Items:					
Annual Facility Maintenance					$20,000
Storage capacity consumed cy/3 yr				29,987	
Available storage capacity at first cycle				1,490,137	
Cycles to replacement of existing CDF yr				49.69	
Number of maintenance cycles completed (There are only 10 cycles in period of analysis)				10	
Number of maintenance cycles remaining				0	
Volume CDF required to accommodate remainder of dredging for period of analysis, plus freeboard and ponding					
In situ sediment volume total cy				0	
Freeboard and ponding (1 cycle requirement) cy				0	
Total volume cy				0	
				cy	**Total Estimated Costs**
CDF Construction Cost		$18			$0
Capping Old CDF		$2	cap volume	0	$0[3]
Capping New CDF		$2			$0

[1] Based on in situ volumes or weights.
[2] Based on processed volumes or weights.
[3] Old CDF is not replaced during period of analysis.

Table C23
Alternative 1 Annual Cost (Interest Rate = 0.0638)

Project Year	Contract Cost (2000 $)	Present Value Factor	Present Value	Present Worth	Cost Item
0	$4,500,394	1	$4,500,394	$4,500,394	Initial dredging- sum of 2 years plus IDC
1	$20,000	0.940071	$18,801	$18,801	Facility maintenance
2	$20,000	0.883733	$17,675	$17,675	Facility maintenance
3	$820,000	0.830771	$681,232	$681,232	Maintenance dredging + facility maintenance
4	$20,000	0.780983	$15,620	$15,620	Facility maintenance
5	$20,000	0.734179	$14,684	$14,684	Facility maintenance
6	$820,000	0.69018	$565,947.85	$565,947	Maintenance dredging + facility maintenance
7	$1,600,000	0.648818	$1,038,109.04	$1,038,109	Capping of old facility
8	$23,475,924	0.609935	$14,318,783.09	$14,318,783	Construction of new facility
9	$820,000	0.573382	$470,173.01	$470,173	Maintenance dredging + facility maintenance
10	$20,000	0.539019	$10,780.38	$10,780	Facility maintenance
11	$20,000	0.506716	$10,134.32	$10,134	Facility maintenance
12	$820,000	0.476349	$390,606.06	$390,606	Maintenance dredging + facility maintenance
13	$20,000	0.447802	$8,956.03	$8,956	Facility maintenance
14	$20,000	0.420965	$8,419.30	$8,419	Facility maintenance
15	$820,000	0.395737	$324,504.15	$324,504	Maintenance dredging + facility maintenance
16	$20,000	0.37202	$7,440.41	$7,440	Capping of old facility
17	$20,000	0.349725	$6,994.51	$6,995	Capping of old facility
18	$820,000	0.328767	$269,588.61	$269,589	Maintenance dredging + facility maintenance
19	$20,000	0.309064	$6,181.28	$6,181	Facility maintenance
20	$20,000	0.290542	$5,810.83	$5,811	Facility maintenance
21	$820,000	0.27313	$223,966.37	$223,966	Maintenance dredging + facility maintenance
22	$20,000	0.256761	$5,135.22	$5,135	Facility maintenance
23	$20,000	0.241374	$4,827.47	$4,827	Facility maintenance
24	$820,000	0.226908	$186,064.75	$186,064	Maintenance dredging + facility maintenance
25	$20,000	0.21331	$4,266.19	$4,266	Capping of old facility
26	$20,000	0.200526	$4,010.52	$4,011	Capping of old facility
27	$820,000	0.188509	$154,577.18	$154,577	Maintenance dredging + facility maintenance
28	$20,000	0.177212	$3,544.23	$3,544	Facility maintenance
29	$20,000	0.166591	$3,331.83	$3,332	Facility maintenance
30	$820,000	0.156608	$128,418.22	$128,418	Maintenance dredging + facility maintenance
31	$1,408,436	0.147222	$207,353.01	$207,353	Capping
	$33,635,924		**$19,115,935.33**		
			Total	**$23,616,329**	
			Capital Recovery Factor	0.07558759	$1,785,101.42
			Average Annual Cost	**$1,785,101.42** **$1,785,100**	

Table C24
Alternative 2 Annual Cost (Interest Rate = 0.0638)

Project Year	Contract Cost (2000 $)	Present Value Factor	Present Value	Present Worth	Cost Item
0	$16,981,084	1	$16,981,084	$16,981,084	Initial dredging- sum of 2 years plus IDC
1	$20,000	0.940071	$18,801	$18,801	Facility maintenance
2	$20,000	0.883733	$17,675	$17,675	Facility maintenance
3	$1,920,352	0.830771	$1,595,373	$1,595,373	Maintenance dredging + facility maintenance
4	$20,000	0.780983	$15,620	$15,620	Facility maintenance
5	$20,000	0.734179	$14,684	$14,684	Facility maintenance
6	$1,920,352	0.69018	$1,325,389.13	$1,325,389	Maintenance dredging + facility maintenance
7	$20,000	0.648818	$12,976.36	$12,976	Facility maintenance
8	$20,000	0.609935	$12,198.70	$12,199	Facility maintenance
9	$1,920,352	0.573382	$1,101,094.73	$1,101,095	Maintenance dredging + facility maintenance
10	$20,000	0.539019	$10,780.38	$10,780	Facility maintenance
11	$20,000	0.506716	$10,134.32	$10,134	Facility maintenance
12	$1,920,352	0.476349	$914,757.47	$914,757	Maintenance dredging + facility maintenance
13	$20,000	0.447802	$8,956.03	$8,956	Facility maintenance
14	$20,000	0.420965	$8,419.30	$8,419	Facility maintenance
15	$1,920,352	0.395737	$759,953.90	$759,954	Maintenance dredging + facility maintenance
16	$20,000	0.37202	$7,440.41	$7,440	Facility maintenance
17	$20,000	0.349725	$6,994.51	$6,995	Facility maintenance
18	$1,920,352	0.328767	$631,347.59	$631,348	Maintenance dredging + facility maintenance
19	$20,000	0.309064	$6,181.28	$6,181	Facility maintenance
20	$20,000	0.290542	$5,810.83	$5,811	Facility maintenance
21	$1,920,352	0.27313	$524,505.21	$524,505	Maintenance dredging + facility maintenance
22	$20,000	0.256761	$5,135.22	$5,135	Facility maintenance
23	$20,000	0.241374	$4,827.47	$4,827	Facility maintenance
24	$1,920,352	0.226908	$435,743.67	$435,744	Maintenance dredging + facility maintenance
25	$20,000	0.21331	$4,266.19	$4,266	Facility maintenance
26	$20,000	0.200526	$4,010.52	$4,011	Facility maintenance
27	$1,920,352	0.188509	$362,003.17	$362,003	Maintenance dredging + facility maintenance
28	$20,000	0.177212	$3,544.23	$3,544	Facility maintenance
29	$20,000	0.166591	$3,331.83	$3,332	Facility maintenance
30	$1,920,352	0.156608	$300,741.70	$300,742	Maintenance dredging + facility maintenance
	$19,603,520		$8,132,695.05		
			Total	**$25,113,780**	
			Capital Recovery Factor	0.07558759	$1,898,290.09
			Average Annual Cost	**$1,898,290.09** **1,898,300**	

Table C25
Alternative 3 Annual Cost (Interest Rate = 0.0638)

Project Year	Contract Cost (2000 $)	Present Value Factor	Present Value	Present Worth	Cost Item
0	$25,487,926	1	$25,487,926	$25,487,926	Initial dredging- sum of 2 years plus IDC
1	$20,000	0.940071	$18,801	$18,801	Facility maintenance
2	$20,000	0.883733	$17,675	$17,675	Facility maintenance
3	$2,670,352	0.830771	$2,218,451	$2,218,451	Maintenance dredging + facility maintenance
4	$20,000	0.780983	$15, 620	$15, 620	Facility maintenance
5	$20,000	0.734179	$14,684	$14,684	Facility maintenance
6	$2,670,352	0.69018	$1,843,024.36	$1,843,024	Maintenance dredging + facility maintenance
7	$20,000	0.648818	$12,976.36	$12,976	Facility maintenance
8	$20,000	0.609935	$12,198.70	$12,199	Facility maintenance
9	$2,670,352	0.573382	$1,531,131.02	$1,531,131	Maintenance dredging + facility maintenance
10	$20,000	0.539019	$10,780.38	$10,780	Facility maintenance
11	$20,000	0.506716	$10,134.32	$10,134	Facility maintenance
12	$2,670,352	0.476349	$1,272,019.11	$1,272,019	Maintenance dredging + facility maintenance
13	$20,000	0.447802	$8,956.03	$8,956	Facility maintenance
14	$20,000	0.420965	$8,419.30	$8,419	Facility maintenance
15	$2,670,352	0.395737	$1,056,756.47	$1,056,756	Maintenance dredging + facility maintenance
16	$20,000	0.37202	$7,440.41	$7,440	Facility maintenance
17	$20,000	0.349725	$6,994.51	$6,995	Facility maintenance
18	$2,670,352	0.328767	$877,922.54	$877,923	Maintenance dredging + facility maintenance
19	$20,000	0.309064	$6,181.28	$6,181	Facility maintenance
20	$20,000	0.290542	$5,810.83	$5,811	Facility maintenance
21	$2,670,352	0.27313	$729,352.50	$729,353	Maintenance dredging + facility maintenance
22	$20,000	0.256761	$5,135.22	$5,135	Facility maintenance
23	$20,000	0.241374	$4,827.47	$4,827	Facility maintenance
24	$2,670,352	0.226908	$605,924.84	$605,925	Maintenance dredging + facility maintenance
25	$20,000	0.21331	$4,266.19	$4,266	Facility maintenance
26	$20,000	0.200526	$4,010.52	$4,011	Facility maintenance
27	$2,670,352	0.188509	$503,384.73	$503,385	Maintenance dredging + facility maintenance
28	$20,000	0.177212	$3,544.23	$3,544	Facility maintenance
29	$20,000	0.166591	$3,331.83	$3,332	Facility maintenance
30	$2,670,352	0.156608	$418,197.39	$418,197	Maintenance dredging + facility maintenance
	$27,103,520		$11,237,950.63		
			Total	**$36,725,876**	
			Capital Recovery Factor	0.07558759	$2,776,020.49
			Average Annual Cost	**$2,776,020.49** **$2,776,000**	

Table C26
Identification of Base Condition and Comparison of Annualized Amounts

Alternative	Initial Investment	Present Value	Annualized Amount	
1	$4,500,394	$23,616,329	$1,785,100	CDF must be replaced after 2 maintenance dredging cycles
2	$16,981,084	$25,113,780	$1,898,300	Life of CDF is extended through 14 maintenance dredging cycles
3	$25,487,926	$36,725,876	$2,776,000	Life of CDF is extended through 49 maintenance dredging cycles